REPORT

ON THE

CHEMICAL EXAMINATION

OF

SEVERAL WATERS

FOR THE

CITY OF BOSTON,

BY

B. SILLIMAN, JR.

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To WALTER R. JOHNSON, ESQ.,

One of the Commissioners appointed to consider the subject of supplying the City of Boston with pure water.

DEAR SIR,—On the 12th of September last, I received from your hands ten samples of water for chemical examination and analysis, and having completed my researches in the best manner in my power in the time allotted, now beg leave to make the following

REPORT.

The waters were handed to me by numbers only, without any designation of their localities, and I still remain ignorant of their sources. They were contained in glass bottles, holding about $2\frac{1}{2}$ gallons each and fitted with well ground glass stoppers. I was informed that the bottles had been filled at the various points from which the water was taken, and that they had not been exposed to the action of the air since they had been collected. I will first give a general description of the waters as regards their *transparency, color, smell* and *taste ;* then their behavior with the various chemical reagents employed to ascertain their contents ;

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and then their ultimate analysis, their action on lead, and some general observations.*

Water Number One.—[From Mystic Pond, about 60 rods above the outlet, taken from the surface, 100 to 150 feet from the shore where the depth was more than 10 feet, collected August 16th at 11.55 A. M.]

Appeared colorless, or nearly so, and quite transparent—on close observation a few flocs of matter were seen floating about—and on looking down vertically through the height of the bottle, some slight departure from perfect colorlessness was perceptible, especially if a sheet of white paper was placed under the bottle. A very trifling quantity of light brownish green sediment was observable in the bottom of the jar, collected into little pellets. No *odor* could be perceived from this water, but it had a saline, brackish taste, like some river waters, and these properties were made more decided by holding a portion of the water in the mouth for a little time.

Number Two.—[Croton River—Taken from the upper reservoir City of New York, near the S. E. corner and near the outlet leading to the distributing reservoir ; collected August 25.]

Was a shade or two less transparent than No. 1, when viewed from above and over white paper—as before mentioned. On the bottom was seen a coat of fur of yellowish matter, as well as some pellets of light spongy sediment in the angles of the bottle. A sheet of paper as seen by transmitted light, when held behind Nos. 1 and 2, appeared decidedly darker through No. 2 than through No. 1. Several lively animalcules were seen skipping about in No. 2 ; none were seen in No. 1. It had a slight sapidity and reminded one of the taste of marsh or swamp water so commonly perceived in the waters of lakes. No *odor* was perceived, and no unpleasant taste was left in the mouth after retaining a portion of it for some time.

Number Three.—[Spot Pond—Taken at 2 P. M., July 17th, 150 to 200 foot from the proposed outlet of conduit, and from the surface,—over a depth of 13 feet.]

Transparent and one or two shades darker in color than No. 2. No animalcules visible, but after agitation a few

* I feel bound to state that I have not seen the results obtained by other chemists who have, as I understand from you, analysed some of these waters, and am quite ignorant how far the results here given will compare with theirs.

small while flocs were seen floating in it. A fur, less in quantity and of a lighter color than in No. 2 covered the bottom of the vessel, and in its angles was a quantity of somewhat dense sediment partly suspended. This water was inodorous—sapid, but less so than No. 2. The color the same.

Number Four.—[Schuylkill, Philadelphia—collected at $4\frac{1}{2}$ P. M. Aug. 23d, 100 to 200 feet above the fore bay in the pool of Fairmount dam.]

Not so transparent as either of the foregoing. It had a slight milkiness, arising apparently from the suspension of white earthy particles. On comparison with No. 3 or 5, it was less colored than either, but less clear. The sediment on the bottom was greater than in either of the former specimens, and of a different quality—denser, darker colored and, not so easily distributed by agitation. No living animalcules were visible. Inodorous, and nearly or quite insipid, perfectly sweet, and like distilled water to the taste.

Number Five.—[Long Pond—collected July 19th, from the point of exit of proposed aqueduct, 150 to 200 feet from shore—Taken from the surface where the depth was 10 feet.]

Transparent and more colored than the foregoing, but by no means *highly* colored—quite free from floating particles—the bottom of the vessel nearly without furry matter adhering to it, and the sediment in the angles about equal to that in No. 2—decidedly less than in Nos. 3 and 4. No animalcules were seen by the naked eye. It was entirely inodorous and tasteless, resembling No. 4 in this respect—perfectly soft and pleasant to drink.

Number Six.—[Charles River—Watertown—collected July 29th, at 6 P. M. 150 to 200 feet above the lower dam, in the middle of the stream.]

Is strikingly like No. 5 in transparency but half a shade darker in color—the furry matter adhering to the bottom was redder and more in quantity, as well as that portion which had collected in the angle of the bottom and sides. No animalcules. Inodorous, but slightly sapid—leaving a somewhat harsh or rough impression on the palate, very different from that of No. 4 or 5.

Number Seven.—[Charles River—South Natick—collected July 22d, at 9 A. M. in the middle of the pool, and 200 feet above the dam.]

Is decidedly darker in color than any of the preceding, and at least three shades darker than the last—the color being brownish yellow. The sediment is not greater than in No.

6, although so much darker in color. No visible animacules and no sensible turbidness—quite transparent. It had a *fresh* odor. Nearly insipid, leaves a pleasant taste in the mouth, and is somewhat unlike the last.

Number Eight.—[Spot Pond—between the island and S. E. shore, at 9 and 13 feet depth from the surface—collected Sept. 3d and 6th.]

This sample presented the most marked differences from all the preceding specimens. It was not so highly colored as No. 7, but the tint of color was different, being greenish yellow, instead of brownish yellow. Its transparency is greatly diminished by the presence of innumerable filaments of a whitish green color, suspended and uniformly diffused in the water, looking like small fibres of linen. These filaments, after the water had remained quiet for some time, rose to the surface in a greenish scum and then the lower portions appeared much clearer—while numerous animalcules were seen darting nimbly in various directions through it. The sediment is but slight—about equal in quantity to that in Nos. 6 and 7. The difference in color is several shades. This water had an unpleasant odor, like that of a faint animal decomposition—by no means agreeable. In taste not so decided as Nos. 1, 2 or 6, but rather sweetish and marshy.

Number Nine.—[Long Pond—upper division, from a depth of 62 feet—collected Sept. 8th.]

Is a water which could not in any sense be called clear or transparent. It is decidedly turbid, of a reddish brown color, while the matter diffused through it is so finely divided as to present no visible points. A very slight coating, only, of furry matter was attached to the bottom of the jar, and the sediment collected in the angles was small and spongy. In color this water is hardly darker than No. 7, when freed from the suspended matter by filtration. Inodorous and slightly marshy in taste, like No 8.

Number Ten.—[Spot Pond—26 feet depth—same locality as No. 8—collected Aug. 26th.]

This extraordinary looking water is as dark colored as many swamp waters, of a deep reddish brown, resembling a solution of iron—and the very abundant sediment at the bottom of the bottle (one quarter of an inch in thickness) is of a still deeper brown. On comparing this water with any of the preceding, so strong a contrast in color is presented as to make it stand alone, since it has more color than all the others united. It is slightly odorous and rather disagreeable but nearly insipid, having less of a marshy taste than No. 9.

It will be seen from the foregoing descriptions that living animalcules were observed in several of the waters, and no doubt could exist in the minds of those acquainted with such subjects, that could the waters be seen when first taken from their various sources, these would be found in them all. But as many of these minute and delicate animals die as soon as they are confined, their absence in any of the above samples would prove nothing ; but the bodies of those which do not suffer immediate decomposition might very naturally be looked for in the sediments. Since some false notions exist in the minds of those who have not considered such subjects particularly—as if the presence of animalcules in a water were an objection to its use for the common purposes of life, I take the liberty to quote the following paragraph from a letter written by Professor J. W. BAILEY, in answer to one from the writer accompanying a sample of each of the waters, with a part of the sediments. He writes as follows :—

WEST POINT, SEPT. 30, 1845.

MY DEAR SIR :—I hasten to send you the results of my examination of the Boston waters, and although they are such as will not help you much in your examinations, I yet give them in some detail, that you may draw your own conclusions.

A portion of the sediment from each bottle, enough to cover a wafer, was placed between the glasses of Chevalier's compressor, and examined by the microscope directly after the bottles were first opened. The contents of each were as follows:

No. 1. A considerable quantity of yellowish brown amorphous matter, probably decomposed vegetable matter, mingled with fragments of straw and fern leaves. A few minute Naviculae, a Fragilaria, and Tabelaria trinodis, rather common.

No. 2. Some fragments of quartz, bits of leaves, and vegetable fibre. Transparent globules with four to nine green globules inside. Eunotia gibba and a few Baccillaria alive, Carapaces of Anuraea stipitata.

No. 3. Much decomposed organic matter as in No. 1, a few particles of sand. Fragments of Entomostraca, Gallionella distans, common. Anuraea stipitata, many specimens of Difflugia proteiformis, a few living Naviculae and minute monads.

No. 4. Organic matter as in No. 1 abundant, minute filaments encased in mucus, minute spheres also. Difflugia proteiformis, Cocconema cymbiforme, Navicula Sigma, Arthrodesmus quadricaudatus, Desmidium hexaceros, and some minute living gelatinous polygastrica.

No. 5. Organic matter as before. Gallionella distans, Desmidium hexaceros, Difflugia proteiformis, Closterium crenulatum. Fragments of Cyclops and Daphne and some living monads.

No. 6. Tabelaria trinodis, Arthrodesmus quadricaudatus, Eunotia monodon, Gallionella distans, Pinnularia viridis, Himantideum arcus, Cocconema cymbiforme, Surirella splendida, Actinophrys Sol, Euglena? alive and active,—Euastrum margaritiferum, some sand and organic matter.

No. 7. Much organic matter as in No. 1. Tabelaria trinodis, Pinularia viridis, Navicula Sigma, Gallionella aurichalcea, Surirella splendida, Synedra ulna, Navicula gracilis, Himantidium arcus, Arthrodesmus quadricaudatus, Cocconema cymbiforme, Euastrum magaritiferum, and several varieties of minute eggs. Spicules of Spongilla.

No. 8. Organic matter as in No. 1. Gallionella distans, Navicula gracilis, Fragilaria pectinalis, fragments of Cyclops, Pollen of Pine.

No. 9. Organic matter as in No. 1. Tabelaria trinodis, Gallionella aurichalcea, Gallionella distans, Surirella splendida, Synedra Ulna, Cocconema cymbiforme, Eunotia Westermanii, Navicula Suecica, Euglena? Anuraea stipitata.

No. 10. Large quantity of rusty looking deposit, containing some minute globules, threads of conferva and Oscillatoria, Gallionella aurichalcea, Tabelaria trinodis, Synedra Ulna, Spicules of Spongilla, living monads.

You will see by the above, that living soft and hard shelled Polygastric Infusoria are present in all these waters, and so far, the evidence is *in favor* of their salubrity, for if they were not present it would necessarily be in consequence of something injurious to animal life being present in the water. Some of the species found are such as inhabit the purest lakes and steams, and many of them would be instantly destroyed in putrescent waters; others are found in peat bogs and stagnant pools.

If you want to know what kind of looking creatures those are whose hard names are given above, you will find them in Ehrenberg's plates.

<div style="text-align:center">Believe me ever, yours truly,</div>

<div style="text-align:right">J. W. BAILEY.</div>

B. SILLIMAN, JR.

There are certain practical questions regarding waters which are to be used for economical purposes, which are of the greatest importance to be considered. Of these, perhaps the most important are—the *softness* of the water, or its adaptation to the purposes of washing where soap is to be

used ; the *nature and quantity of the solid contents left on evaporation*—a question of the greatest interest where the water is used for generating steam, either in stationary or locomotive steam boilers ; and, intimately connected with this point, the *general adaptedness* of the water to *all* the domestic and other purposes of common life ; and its *freedom* from any, or all those foreign bodies which can, in any way, be considered as deleterious to the health of the consumer.

The action of water on *metallic lead* is another question which must be allowed to be of great weight, since it is the almost universal custom to carry water into houses, from the iron pipes of supply, in pipes of lead—as well as to employ the same metal in wells where pumps are used. The poisonous effects of some of the soluble salts of lead are well known, and all plumbers know with what rapidity, in certain situations, leaden pipes are destroyed by a corrosive action of the water.

It will be seen that a set of comparative experiments has been made on these waters, in reference to this question, which is believed to have some value.

We will first speak of the *softness* of the various samples examined. The test employed to determine this point was an alcoholic solution of common soap, commonly known as tincture of soap. In *hard* waters this test, when added in proper quantity, produces an immediate cloudiness and a precipitate if the water is very hard. It should be remarked that lime and magnesia are the substances which produce the quality commonly known as *hardness* in waters. Common salt and various other matters may be present in waters, in considerable quantity, without producing a cloudiness in the soap test ; but this test may be safely relied on by those who are unacquainted with chemistry, as giving a very sure indication of this property, of so much importance in the concerns of common life.

In water *No.* 1, the soap test produced an immediate and very thorough milkiness, showing it to be a decidedly *hard* water. Common writing could not be discerned in the least, when held behind the test glass, (a common wine glass.)

No. 2. Was rendered turbid in about half the degree that No. 1 was. Handwriting could be seen through it.

No. 3. But little turbidness appeared on adding the soap test to this water, and it must be considered nearly soft.

No. 4. Nearly similar to No. 3, but slightly more disturbed.

No. 5. Is hardly rendered in any degree turbid—not more than common rain water.

No. 6.   Is identical in character with No. 3, and rather better than No. 4.

No. 7.   The same as No. 3 and 6.

No. 8.   The want of transparency natural to this water was a little increased by the soap test.   It would fall between Nos. 7 and 5.

No. 9.   Has the same degree of opalescence as Nos. 3 and 6—but some deduction must be made for the degree of turbidness of the water in its natural state.

No. 10.   About the same as No. 3—but the high color of this water interferes with a proper judgment.

We may arrange these results in a numerical order which shall express the greatest excellence by the order of the numbers, beginning with the best and descending in regular order.   We have then,

No. 5, 8, 6, 7, 9, 3, 4, 10, 2, 1.   The real difference between Nos. 5, 6, 7, 8, and 9, is very small, and can be seen only by comparison.   After the test glasses containing the above results had stood forty-eight hours, marked changes were observed in them.   Some of the clear ones had become more turbid, and the following order was observed,

No. 9, 10, 6, 4, 8, 7, 5, 3, 2, 1.

The nature of the solid matters and their action on metallic lead, two points of inquiry above alluded to, will be considered further on.

The well known reagents gave evidence of the presence, in nearly all the waters, of chlorine—sulphuric acid—crenic and apocrenic acids—carbonic acid—phosphoric acid (in some, nitric acid)—lime—magnesia—alumina—silica—potash—soda—and rarely iron—and manganese.   These substances, in their various forms of combination, were present in very minute quantity only, in several, requiring great care or peculiar management to render them sensible.   But when we remember how powerful a solvent water is, it should not surprise us that it takes up such matters as it meets with in falling on the surface of the earth ; and we should rather wonder that it is as pure as we generally find it, rather than that it contains a long catalogue of foreign substances.

Some remarks are required, to notice the peculiarities of the reaction of some of the waters with the various reagents employed.

Chlorine.—A portion of each water, acidulated by pure nitric acid, was tested with nitrate of silver.

No. 1 gave a prompt and abundant precipitate of chloride which, on exposure to light, grew rapidly dark, and at last black.

In all the others (Nos. 2, 3, 4, 5, 6, 7, 8, 9 and 10) the silver test gave scarce any visible cloudiness, from the production of chlorides.

It is a fact well known to chemists that nitrate of silver is a very sensitive test for the presence of organic matter in water, when exposed to sun-light, especially for certain acids with which it forms beautiful pink, violet and purple compounds. On setting the test glasses used in the above experiments in the sun-light, to facilitate this reaction, in a very few moments great changes became evident in all. No. 1 became deep violet purple. Nos. 2, 4, 5, 6, 7 assumed a delicate pinkish color, like solutions of cobalt—No. 2 being the most intense and the color diminishing in the order of the numbers. It will be remembered that scarcely any traces of chlorine were detected by this test in these numbers. The same effects were seen, to a greater or less extent, in all. On standing for twenty-four hours, the precipitate in No. 1 had fallen and left the water above clear and colorless, while the abundant mass of chlorides had become quite black from the action of the sun's light. The glasses containing the other samples presented a most beautiful display of different shades of pink, purple, violet and maroon colors. In Nos. 5, 6, and 7, not the least precipitate had fallen; the water was of a rich wine color, while a film of metallic silver was seen floating on the surface, reduced by the deoxidising power of the organic matter in the water. Nos. 2 and 3 had some precipitate of a reddish brown adhering to the sides of the glass, and the water was of a high color. No. 4 had the precipitate suspended, rendering it turbid, and of a violet pink color. No. 8 resembled No. 2. No. 9 was like Nos. 5, 6, and 7, but had some precipitate adhering to the sides of the vessel. While No. 10—so highly colored by nature—had grown nearly colorless, and a bulky, rusty colored precipitate had fallen.

It was inferred from the above trials that, with the exception of No. 1, very little chlorine combined with alkaline bases would be discovered in these waters, on the analysis of the solid matters resulting from the slow evaporation of a large quantity; this inference, it will be seen, is borne out by the results obtained. However, it is also evident, that the presence of the organic matters materially hindered the action of the chlorine test, since not one of the waters was entirely free from this ingredient.

In waters containing a large quantity of chlorine in union with ammonia, it is quite unsafe to trust the solid matter, obtained from the evaporation of a known quantity, as truly representing all the solid contents of the water—since large

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losses are incurred by the volatilization of some of the compounds present. We are in a great measure freed from the liability to this kind of error in the analysis of these waters because of the general absence of salts of ammonia.

It has been remarked that, from the action of these waters with the silver test, it was inferred that organic acids were present. The next step of inquiry was to ascertain whether any of the waters were *alkaline or acid*, or whether they were all *neutral*. They might be acid, either from the presence of *free carbonic acid gas* in considerable quantity, or from the presence of some *free organic acid ;* while it is obvious that an excess of *free alkaline salts* would give them an alkaline reaction.

A sensitive tincture of blue litmus was freshly prepared in alcohol, and five or six ounces of each water being placed in test glasses of uniform size, a few drops of the blue tincture were added to each—enough to impart a decided color. A similar portion of newly boiled and pure distilled water was also treated in the same way, as a standard of comparison. After sufficient time had elapsed—no change of color was seen in Nos. 1, 2, 3, or 4. Nos. 5 and 6 had become slightly reddened (*very* slightly). Nos. 7 and 8 unchanged. No. 9 was decidedly reddened—No. 10 still more so—and both became still redder on the addition of more of the test. It appeared therefore that there was a free acid of some sort in Nos. 5, 6, 9 and 10. None of the waters exhibited any alkaline reaction.

It now became interesting to determine the nature and comparative quantity of the organic acids which were present. BERZELIUS, in his well known examination of the waters of the Porla well in Sweden, first made known to us the existence of two peculiar organic acids which he detected in that water, and which had before been overlooked and confounded under the general name of " *extractive matter,"* and various similar names. These acids he called the *crenic and apocrenic* (from the Greek κρηνη, *a fountain*). The latter is spontaneously formed from the former, and differs from it considerably in the proportion of its ingredients.[*] Crenic acid is easily altered in composition, and, in the presence of air and a proper temperature, is rapidly transformed into apocrenic acid—growing brown in the operation and imparting this color to the water containing it. A striking example of this is

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[*] HERMANN found crenic acid to contain, in 100 parts—carbon 40.24—hydrogen 7.69—nitrogen 7.50—oxygen 44.57 ; and apocrenic, carbon 62.57—hydrogen 4.80—nitrogen 15—oxygen 17.63. And the chemical formulas expressing their composition to be, respectively, $C\ 16\ H\ 16\ NO\ 6$ and $C\ 14\ H\ 14\ O\ 3\ N\ 3$.

seen in No. 10, which contains a large quantity of apocrenic acid. The salts of lead and copper both form insoluble compounds with these acids, but, as the basic acetate of lead also forms insoluble compounds with numerous other organic matters which may be present in water—it is best to employ the acetate of copper in testing for these acids. This test produces with crenic acid a greenish white precipitate which quickly subsides—while if apocrenic acid be present, it forms a brown coffee colored preciptate which is deeper in color in proportion, as the quantity of apocrenic acid is greater ; the former is soluble in an excess of acetic acid and while the latter is insoluble, offering a ready means for their separation.

Neutral acetate of copper was added to each of these waters in the cold and without any concentration by boiling. No *immediate* precipitate was found except in No. 10. But after standing for twenty-four hours, there was a precipitate in all but No. 8, which appeared quite clear. Both *crenic and apocrenic acids* were thus detected in the waters—in some only the former, in others a mixture of both. Crenic acid was found most abundantly in Nos. 2, 4, 1 and 5—and in abundance according to the order of the numbers. No. 2 afforded a most copious greenish white precipitate of crenate of copper.

Apocrenic acid was seen most copiously in No. 10, which had quite a bulky, dark brown precipitate, while the water had lost entirely its natural brownish yellow color—having only a slight green from the excess of the reagent employed. Nos. 9, 7, 5 and 3, had each some of the same—very decided and abundant in Nos. 9 and 7—much less so in No. 5, and very little in No. 3. The determination of the precise quantity of these acids in the waters, was not undertaken as it was suposed the public interest did not require it.

The next head of inquiry, and one somewhat related to the last, was the presence or absence of *carbonic acid.* We may presume that there is no natural water—unless a very acid one (like some springs and rivers which contain free sulphuric acid) which is quite without this gas. All waters we know will absorb atmospheric air, and as this always contains a small quantity of carbonic acid gas, we should naturally be led to expect its presence in all waters. But there are other and more abundant sources of carbonic acid in waters than the small quantity contained in the air. The decomposition of vegetable matters contained in the various sources of water, and natural supplies of this gas from the earth, are the most obvious ways in which carbonic acid may be made to impregnate natural waters. Since it has been supposed that the presence of a considerable quantity of this gas in a water was

one principal source of the corrosion of leaden pipes used for the conveyance of water, it seemed to me to be a question of some practical interest to determine, as nearly as could be, the actual amount of this gas in the several specimens in hand.

Amount of carbonic acid gas in the waters. The method used to determine this question was that recommended by BERZELIUS, which consists in conducting all the vapors and gases, given off during the boiling of a known quantity of the water to be examined, by means of a glass tube into a close vessel containing a quantity of ammoniacal lime water. The details of the apparatus need not be here given. The carbonic acid gas combines under these circumstances with the ammoniacal lime water, forming a carbonate of lime; not a bubble escapes; and the carbonate of lime resulting being collected and weighed, we have by an easy calculation the amount of carbonic acid in weight, which is easily turned into cubic inches of gas. Although this method is subject to some objections in cases where *extreme* accuracy is required, it is believed that the results obtained by it are close approximations to truth, and it is certainly more accurate than some other methods which are recommended on high authority. The examination was made on one fourth of a gallon, United States standard measure, about 58 cubic inches, and the results calculated for the standard gallon of 231 cubic inches, weighing at 60° Fahrenheit, 58,364.6509 grains Troy.*

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* All the quantities of water used in these experiments were determined *by measure* in the United States standard gallon of brass, adjusted to hold, with its accurately fitted cover of ground glass, at the temperature of 39°.83′ Fahr. (the point of maximum density in water)—58.372.1754 American standard Troy grains of pure distilled water. The temperature of the waters when measured in these experiments, was as nearly as possible 59°.5 Fahr.=15° C. Now, 10,000,000 parts of pure water expand, between the temperatures of 39°.83 Fahr. (viz. the temperature at which these measures are adjusted) and 59°.5 Fahr. (that at which the measuring of those waters was actually made) 10.007. 357 parts; while a brass vessel holding 10,000,000 parts by bulk at the former temperature, will hold 10,006,067 at the latter; the difference of these, viz. 1200 parts, in the portion of the whole bulk of water which will be excluded. Now $\frac{1290}{10,007,357} \times 58,372.1754 = 7.5245$ grains, which is the weight of the excluded portion, leaving the gallon of distilled water at 15° C=59°.5 Fahr. weighing 58,364,6509 grains. Any one who has seen these beautiful instruments cannot doubt that when we operate with quantities so large as were used in my experiments, far greater accuracy, (and immeasurably greater economy of time) can be obtained by using the method of measuring in preference to weighing. Our balances of precision are usually overloaded with about 1500 to 2000 grains—while by the use of pure distilled water to rinse out the last adhering traces of the water from the measure, no appreciable error can be introduced into the analysis. In case of the determination of *carbonic acid*, care was used that the distilled water employed to wash out the vessel, should be freed from carbonic acid by recent boiling. By the kindness of the Collector of Customs at this port, I was allowed access to the set of United States standards which were employed in these researches. The weighings throughout were made in

The weights of carbonate of lime obtained in a quarter of a gallon by the process for carbonic acid, give the following results in *cubic inches* for one gallon of each water.

No. of Water.	1	2	3	4	5	6	7	8	9	10
Volume per gallon of carbonic acid.	10.313	17.41?	9.516	3.879	10.719	5.058	0.464	5.163	4.549	a trace.

None of the other gaseous constituents of the waters were estimated. A salt of lead (basic acetate) showed, from the yellowish white precipitate it formed in them all, the entire absence of sulphuretted hydrogen gas which, if present, even in a very minute quantity, would of course have made a dark colored precipitate of sulphuret of lead. *Carbonic acid* ought to he estimated *at the source* from which the water is obtained, as its quantity is very apt to vary on removal, and a difference in the tightness of the stoppers and various other causes may cause discrepancies in the results obtained. In No. 10, which contained so large a quantity of organic acids, no carbonic acid could be found.

The same sample of water from which the carbonic acid had been expelled, was employed to estimate the quantity of sulphuric acid. They were all rendered acid by hydro-chloric acid, and *while boiling*, the sulphuric acid was thrown down in combination with baryta by the addition of a sufficient quantity of chloride of barium.

In most, the quantity of sulphuric acid appeared exceedingly small—as judged of by the feeble amount of sulphate of baryta precipitated. So small a quantity, indeed, is present in most of them, that when taken in the cold and unacidulated, no reaction can be perceived in any but No. 1. But by the method described, we obtained the following quantities, calculated for one standard gallon, in Troy grains.

No. of Water	1	2	3	4	5	6	7	8	9	10
Sul. acid in one gallon.	.1058	.0055	.00824	.0245	.0044	.010	.00137	.011	.0037	.00246

In evaporating a portion of each to a small bulk (about

French *grammes* and decimals of a *gramme*, which were applied with precision to the first decimal of a *milligramme*. But as these most convenient weights are not usually employed in this country, I have converted them into grains and decimals—taking the French *gramme* to be 15 444 grains. From the data here given, it is easy for any person to calculate the relation of the results obtained to a gallon, to 1000 parts by weight.

1-10th) it was seen that in most of the waters a precipitate took place of matter no longer soluble; this precipitate was specially abundant in Nos. 1 and 2. It was white and granular. More particular notice will be taken of it in the account presently to be given of the determination of the solid contents of each water.

From the water thus condensed by evaporation, and filtered to free it from the suspended granular matter, *magnesia* was thrown down by ammoniacal phosphate of soda, the lime having been also previously removed by oxalate of ammonia. This earth (magnesia) was seen in considerable quantity in No. 1—also in No. 2 abundantly, but less than No. 1—No. 4 but little—Nos. 3, and 5 to 10 inclusive, in slight quantity—but not absent from any.

Iron. The test preferred to ascertain the presence of this body was the tincture of gall nuts. About two ounces of each in test glasses were mixed with a few drops of tincture of galls. But little effect was observable at first, but on standing twenty-four hours, the reaction was very well marked. Arranged in the order of the brown color produced by this test with iron, the series will be 10, 9, 1, 6, 8, 2, 4, 3, 7, 5. Only in No. 10 is the reaction *very* decided—this test makes a deep brown almost black color with the galls. No. 9 not half so much, while in No. 1 it is slight and declines regularly to No. 5, which is hardly discolored at all : Nos. 3 and 4 were rendered also quite opalescent.

Ammonia was looked for without success by the usual precautions in employing caustic soda as a test, but had the vapor from the evaporation of a large quantity of the water been conducted through muriatic acid, it is quite probable that some traces of this agent would have been discovered.

Lime.—This was most abundant in No. 4, as indicated by the oxalate of ammonia. Nos. 2 and 1 stood next—Nos. 8, 7, 9 and 10 next—while Nos. 3, 5, and 6 were nearly exempt.

With these statements we may safely proceed to the question of the actual amount of solid matter in each, as determined by the gradual evaporation of a standard gallon. A carefully measured standard gallon of each sample was taken. The evaporation of Nos. 1, 2 and 3 was performed in open basins of porcelain with covers of paper, as recommended by BERZELIUS; but as several objections exist against the use of open porcelain basins, chiefly from the free access of dust and foreign bodies and the difficulty of removing the film which sometimes obstinately adheres to the sides of the vessel—occasioning loss—I found it best, on many accounts, to employ flasks of green glass holding about a quart each, and placed on a range of iron plates where the temperature was

that of gentle ebullition, and the atmosphere about the sides of the vessel so hot as to prevent the condensation of the steam and consequently the return of a portion already evaporated to the liquid state in the vessel. As the volume of the water diminishes, the contents of one of the vessels can be safely turned into another, without loss, until the four are reduced to one. When each water was in its turn reduced to about 4 or 5 ounces of bulk, it was removed to a small capsule of known weight, and carried to complete dryness over a water bath at a heat of 212° Fahr. After this it was carefully cooled over sulphuric acid on an air pump, and weighed before it began to acquire weight by attracting hygrometric moisture. If the weight was not found constant, it was again warmed, cooled as before, and then weighed again. During the evaporation, numerous changes took place in the appearance of the several waters, which it is interesting to note.

No. 1 became somewhat discolored by boiling and threw down a light brownish matter which increased in quantity as the evaporation continued; when carried to dryness it presented a pretty abundant crystalline crust of whitish salts, and had very little appearance of organic matter on the sides of the capsule—but on the bottom some slight traces. On standing in the air it vegetated on the edges of the capsule, and when ignited to burn off organic matter, it showed not the least deflagration from the presence of nitrates.

No. 2 also grew rusty on boiling and threw down a somewhat granular and abundant coffee colored precipitate. Carried to dryness, it gave a brownish yellow, earthy, quite uncrystaline residuum with a deep brown areola of organic matter on the edges of the capsule. The earthy matters collected at the bottom of the capsule cracked on drying, like an aluminous residue. On igniting this residuum, there was a most brilliant deflagration from the presence of nitric acid, which was sufficient to completely burn off, in an instant, all the dark colored organic matter—and a perfectly white earthy powder was left.

No. 3 was very similar to the last, but changed less by the ebullition. The quantity of solid matter was much less than the last, and it contained less organic matter, which burnt off quietly without deflagration.

No. 4 became quite milky when reduced to half its volume from the suspension of a white precipitate which fell on cooling; when reduced to a pint, it became *very* milky and yellowish (carbonate of lime and magnesia.). When quite dry the result was very different from either of the foregoing, being a cream colored, small granular, earthy powder—with a

slight areola of organic matter ; and on ignition a well mark-
ed deflagration took place from the presence of nitrates.

No. 5 became decidedly ferruginous as it evaporated, but
the quantity of solid matter was very small—of a light ash
gray, with a yellowish brown organic film on the sides of the
crucible ; there was a small deflagration from the presence of
nitrates.

No. 6, as the evaporation proceeded, became filled with
numerous floating scales, of a bright lustre and transparent,
which were probably sulphate of lime ; a pellicle or crust
formed on the surface of the capsule at the close of the evap-
oration, while a slight deflagration was observed on ignition.

No. 7 when condensed to one fourth of its bulk, became
very ferruginous—as much so as No. 5—and showed the
same bright scales as were seen in No. 6 ; and as the evapo-
ration proceeded it looked less ferruginous. When dried up
it left a glairy, cream-colored crust—not in the least crystal-
line—with a small areola of organic matter ; on ignition it
emitted strongly the smell of burnt hair or horn—with no
deflagration.

No. 8 appeared at first to grow brighter by boiling and
looked much clearer than in the jar ; but when about a quar-
ter part was gone, it began to grow thick from the suspen-
sion, apparently, of organic matter, looking farinaceous. As
the process went on, this appearance diminished and the bril-
liant scales noticed in No. 6 appeared. When dried, it left
an abundant, fine granular, yellowish gray residue with an
iridescent film such as is seen on the surface of water con-
taining iron.

No. 9 grew very red and rusty from the suspension of a
finely divided, reddish powder ; this powder collected into
balls as the water condensed and bright scales, as in No. 6,
appeared. The solid matter condensed very much as the
evaporation proceeded but was still abundant. The dry re-
sidue of evaporation was bulky, earthy, cracked on drying,
and had a highly iridescent film over the surface.

No. 10 became deep wine red color on boiling, having a
pulpy, ferugenous precipitate in which were seen the same
scaly crystals as in No. 6. These appearances altered mate-
rially as the evaporation proceeded, and on drying over the
water-bath, became reddish gray, light colored, and cracked
like alumina or hydrous peroxide of iron. It had also on
ignition a slight deflagration from the presence of nitrates.

The amount of solid matter to the standard gallon of each
water, as determined by this series of evaporations, is ex-
pressed by the following table.

Number of water.	1	2	3	4	5	6	7	8	9	10
Solid matter in 100,000 parts by weight.	50.752	18.714	3.647	9.417	3.168	5.702	4.332	5.308	5.770	10.598
Grains of solid in 1 gallon.	39.710	10.93	2.13	5.50	1.85	3.40	2.53	3.10	3.37	6.19
Volatile at redness.	6.02	4.28	0.86	1.24	0.63	0.85	0.86	1.00	1.16	1.58
Leaving solid matter.	33.68	6.66	1.25	4.26	1.22	2.55	1.668	2.10	2.21	4.62
Of which there was soluble in hot water.	32.45	2.49	0.69	0.57	0.53	0.93	0.758	0.79	0.48	0.73
Insoluble.	1.24	4.47	0.56	3.69	0.69	1.62	0.910	1.31	1.73	3.89

The matter volatile at redness was not only all organic matters present, but also nitric acid, water chemically combined with the salts, and possibly the chlorine combined with the magnesia, as well as any salts of ammonia—evidently leaving too much latitude for loss to afford us the most accurate results on the analysis of the non-volatile residue. But my instructions made the determination of the *actual solid matters* a point of considerable importance, and the results which follow show that in those cases, like Nos. 1 and 3 and others, where the amount of volatile matter was small and no nitrates were present, and consequently but a small amount of alkaline bases unengaged by electro-negative affinities— the loss on the analysis was not more than was reasonably to be expected. But in cases like No. 2, where a great amount of crenic and nitric acids were present in combination with soda or other bases—and that base was estimated by the loss and not directly—it is quite evident to those acquainted with chemical analysis that the results would show a corresponding loss. After ignition and treatment with water, the solution of each was found to have a strongly marked *alkaline* reaction—confirming the remarks just made that soda was combined with some volatile acid which, on ignition, left the alkaline bases free, or converted them into carbonates. A careful analysis was performed on each sample, both on the soluble and insoluble ingredients; and this double work—on quantities so small as those found in the majority of cases (only about half a grain in the case of 3, 4, 5 and 9, and not much more in the others—see table) —requiring a multiplicity of operations—and attended with the addition of so many hundred times the quantity of the various reagents employed—presented in itself difficulties enough, aside from the presence of matters which under the circumstances could be determined only from the loss. The results will speak for themselves. I will only say that in reconstructing the supposed condition of the various ingredients found, as they *probably* existed in the waters, the rule adopted has been to follow as nearly as possible the order of affinities of the various elements concerned, and to obey also as

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nearly as we were able, that partition of acids among bases which undoubtedly obtains in nature.   It is indeed the opinion of BERZELIUS, ROSE and other eminent chemists, that the effort to restore with accuracy the precise condition of the elementary combinations concerned in a mineral water, is altogether futile—except in cases of extraordinary simplicity; and that it is the better way to state only the quantities of the various ingredients found, and leave it for the ingenuity of the student to reconstruct them as he finds most convenient.   In my analysis of the waters of the Dead Sea I have followed this principle.   [American Journal of Science—Vol. 48, page 10,] and had almost determined to adopt it here.   But on more reflection, considering the somewhat popular nature of this report, I have determined to present the results in the more usual form of chemical analysis—as being more likely to meet the public expectation.

No. 1 gave us the following results.

Chloride of sodium (common salt) - - -	27.9111
Chloride of potassium, - - - - -	.1590
Chloride of calcium, - - - - - -	.1544
Sulphate of magnesia, - - - - -	1.9768
Sulphate of alumina, - - - - - -	.4478
Phosphate alumina and trace of iron, - - -	.2810
Carbonate of lime, - - - - - -	.1698
Carbonate of magnesia, - - - - -	.9894
Sulphate of lime, - - - - - -	.1219
Silica, - - - - - - - -	.5559
	32.7671
Actual amount after ignition, - - - -	33.6833
Loss, - - - - - - - -	.0162

Carbonic acid in 1 gallon, in cubic inches, - - 10.313

The principal constituent of this water it seems is common salt, united however to an uncommon number of other substances in small quantity.   The presence of *phosphoric acid* in water has generally been overlooked, because unsuspected. It has escaped under the general title of alumina and iron, with which it is thrown down on addition of caustic ammonia.   If this precipitate is entirely soluble in acetic acid, no phosphates are present; if however a portion is left undissolved after long digestion with acetic acid, it should be collected and weighed, and then examined for phosphoric acid.*

* To determine beyond question the existence of phosphoric acid, the phosphate of alumina was fused (that of No. 2) with one part of silica and six parts of pure carbonate of soda, in a platinum crucible for half an hour—the fused

It is certainly interesting to observe that a compound indispensable to the full developement of the human frame should be so widely diffused as to be present, in minute quantity in almost all natural waters. We are less surprised at this fact now than we should have been a few years ago, since we now know that phosphoric acid is found in granite, mica slate, various lime stones of all formations, as well as in many simple minerals where it had before been overlooked ; and I have detected its presence in connection with *fluorine*, in most recent corals and coral limestone—and Dr. JACKSON informs me that in his analysis of sea water for the Exploring Expedition, he also detected phosphoric acid. The same fact was independently proved by Mr. SCHWEITZER, in his analysis of deep sea water from the British Channel. It will be seen also, that silica is an almost constant element in these waters, being present of course in their natural state in its soluble modification.

No. 2. This was one of those waters which contained a large quantity of crenic acid and nitric acid, and of course we had an excess of carbonate of soda corresponding to these acids. It gave an analysis as follows :

Chloride of sodium and a trace of potassium,	.167
Sulphate of soda,	.153
Chloride of calcium,	.372
Chloride of aluminium,	.166
Phosphate of alumina,	.832
Carbonate of lime,	2·131
Carbonate of magnesia,	.662
Sulphate of lime,	.235
Silica colored by manganese,	.077
*Carbonate of soda, equivalent to nitrates and crenates of ditto, and loss,	1.865
Total solid in 1 gallon, after ignition,	6.66
Carbonic acid in ditto in cubic inches,	17.817

The peculiarities in the composition of this water are the large quantity of carbonic acid holding up lime (which it will

masses treated with water and filtered—carbonate of ammonia was added, and, by digestion and evaporation, the silicic acid removed. The filtrate, rendered quite neutral, was treated with nitrate of silver, which promptly threw down the characteristic precipitate of *yellow tribasic phosphate of silver*—blackening by light, and readily soluble in dilute nitric acid. No better proof can be asked. This is the process which BERZELIUS recommends for separating phosphoric acid from alumina.

* The crenic acid of No. 2 was separately estimated and found to be equal to 1.1734 grains to the gallon.

be remembered fell on boiling,) the large relative proportion of phosphate of alumina, and the crenic and nitric acids.

No. 3.   This water contained less solid matter to the gallon than any other—save No. 5—and lost very little by ignition ; nor did it possess crenic acid.   Consequently it presents an analysis very nearly exact in quantity, as follows:

Chloride of sodium, - - - - - -	0.3969
Sulphate of soda, - - - - - -	0.2276
Alumina, iron, and phosphates of ditto, - -	0.1081
Carbonate of lime, - - - - - -	0.3722
Carbonate of magnesia, - - - - -	0.1420
	1.2468
Actual amount found by evaporation, - - -	1.2500
Loss on analysis, - - - - - -	0.0032
Carbonic acid gas in 1 gallon, in cubic inches, -	.9.516

No. 4.   This water differed materially from the foregoing in the amounts of carbonates of lime and magnesia, as well as in organic matters and nitric acid.   It gave as follows.

Chloride of sodium, - - - - - -	.1470
Chloride of magnesium, - - - - -	.0094
Sulphate of magnesia, - - - - -	.0570
Carbonate of lime, - - - - - -	1.8720
Carbonate of magnesia, - - - - -	.3510
Silica, - - - - - - - -	.0800
Carbonate of soda, from decomposed Crenates and Nitrates, and loss on analysis, - - - -	1.6436
	4.2600

On treating the solid residue of this water with hydrochloric acid a very brisk effervescence took place.   It contained, it will be remembered 3.879 cubic inches of carbonic acid gas to the gallon.

No. 5.   This water stands by itself in containing less solid matter to the gallon than any other, and in the feebleness of its reactions with nearly all the tests—although the analysis shows that it contains nearly all the ingredients found in any other of the ten, but in very small quantity.   Having an abundance of this water, we frequently drank small quantities of it during the investigations, and became quite partial to it. Its analysis gave the following results.

Chloride of sodium, - - - - - -	.0323
Chloride of potassium, - - - - -	.0380
Chloride of calcium, - - - - - -	.0308

Chloride of magnesium, - - - - -	.0764
Sulphate of magnesia, - - - - -	.1020
Alumina, - - - - - - - -	.0800
Carbonate of lime, - - - - - -	.2380
Carbonate of Magnesia, - - - - -	.0630
Silica, - - - - - - - -	.0300
Carbonate of soda, equivalent to Crenate and Nitrate of ditto, and loss, - - - - -	.5295
	1.2200
Carbonic acid in 1 gallon, in cubic inches. - -	10.719

No. 6 closely resembles No. 5 in the proportion and number of its constituents, which are as follows.

Chloride of sodium, - - - - - -	.1984
Sulphate of soda, - - - - - -	.0830
Sulphate of potassia, - - - - - -	.0310
Sulphate of magnesia, - - - - -	.1350
Phosphate of alumina and free alumina, - -	.0830
Carbonate of lime, - - - - - -	.4970
Carbonate of magnesia, - - - - -	.1300
Sulphate of lime with silica, - - - -	.6810
Carbonate of soda, equivalent to Crenate and Nitrate of ditto, and loss, - - - - -	.7116
	2.5500
Carbonic acid to the gallon, in cubic inches, -	5.058

No. 7, on analysis of its solid constituents, gave the following results.

Chloride of sodium, - - - - - -	.1547
Sulphate of soda, - - - - - -	.3816
Chloride of calcium, - - - - - -	.0420
Sulphate of lime and silica, - - - -	.2624
Phosphate of alumina, - - - - -	.0973
Carbonate of lime, - - - - - -	.1610
Carbonate of magnesia, - - - - -	.0399
Carbonate of soda, equivalent to Crenate and Nitrate of ditto, and loss - - - - -	.5291
	1.6680
Carbonic acid in 1 gallon, in cubic inches, - -	0.464

No. 8 gave the following results.

Chloride of sodium, - - - - - -	.1553
Sulphate of soda, - - - - - -	.1510

Chloride of calcium, - - - - -	·0044
Sulphate of magnesia, - - - - -	.1290
Sulphate of lime and silica, - - - -	.4940
Phosphate of alumina, - - - - -	.0740
Carbonate of lime, - - - - -	.0490
Carbonate of magnesia, - - - - -	.1030
Carbonate of soda, and loss, - - - -	.9403
	2.1000

Carbonic acid to the gallon, cubic inches, -   - 5.163

No. 9 gave the following results.

Chloride of sodium, - - - - - -	.2540
Sulphate of soda, - - - - - -	.0843
Sulphate of alumina, - - - - - -	.0146
Sulphate of lime and silica, - - - -	.5700
Phosphate of alumina, - - - - -	.1700
Carbonate of magnesia, - - - - -	.2560
Carbonate of lime, - - - - - -	.3860
Carbonate of soda, equivalent to Crenate and Nitrate of ditto, by loss, - - - - -	.4757
	2.2100

Carbonic acid gas in 1 gallon, cubic inches, -   - 4.549

This water also contained traces of iron which were too small to estimate; it was associated with phosphoric acid and alumina.

No. 10.—This very peculiar looking water gave the following results—and from the large quantity of iron it is easy to understand its high color, as well as from the abundance of apocrenic acid and organic matters.

Chloride of sodium, - - - - - -	.2230
Chloride of magnesium, - - - - -	.0144
Sulphate of magnesia, - - - - -	.0570
Sulphate of lime with silica, - - - -	2.0700
Basic phosphate of iron, and phosphate of lime, -	1.3600
Carbonate of lime, - - - - - -	.3410
Carbonate of magnesia, - - - - -	.2730
Alumina and phosphate of ditto, - - -	traces
Carbonate of soda, equivalent to Crenates and Nitrates of ditto, and loss, - - - - -	,2816
	4.6200

This water contained no measurable quantity of carbonic acid, but it may be safely asserted that at its source it does

contain a portion of this gas, holding up iron as proto-carbonate of iron ; numerous scales of dark brown color floating about among the sediment confirm this statement. A large quantity of this sediment was dried off at 212° Fahr. over a steam bath in a platinum vessel, and ignited to expel the organic matter ; it burnt up almost completely, leaving only a little oxide of iron, and during the combustion emitted a strong odor like burning hair. It is also highly probable that the carbonate of lime and magnesia above noticed were held in solution by organic acids.

REMARKS.

On comparing the foregoing results with one another, and with analyses of other waters, we must admit that, if Nos. 1, 2, and 10 be excepted, they are all remarkably free from foreign matters, and that what they do contain, cannot—with the above exceptions—be much objected to. Indeed, Nos. 3 and 5 are almost good enough for any chemical purpose whatever. A water which will dissolve nitrate of silver without cloudiness, and will produce no precipitate with a salt of baryta, must be allowed on all hands to be *very pure*, although not absolutely so.

It is interesting in the connection to compare the results here given with those obtained from the analysis of other waters. This I am enabled to do through the kindness of Dr. James R. Chilton of New York, who at my request, has sent me the following analyses of the *Croton* water, made by himself.

FROM THE CROTON RIVER.

Chloride of Calcium, }	
Chloride of Magnesium, } - - - -	.86
Carbonate of lime, - - - - - -	1.42
Carbonate of magnesia, - - - - -	.70
Vegetable matters, &c. - - - - -	.34
	————
Grains in 1 gallon, - - - - - -	3.35

FROM THE HYDRANT.

Chloride of calcium, }	
Chloride of magnesia. } - - - -	.90
Carbonate of lime, - - - - - -	1.52
Carbonate of magnesia, - - - - -	.84
Sulphate of lime, - - - - - -	.44
Vegetable matter, &c., with a trace of iron, - -	.46
	————
Grains in 1 gallon, - - - - - -	4.16

Dr. CHILTON remarks, "that these analyses were made a short time after the introduction of the water into the city. The difference in the two may be owing to the passage, in one case, of the water through thirty miles of cemented way. It is probable that at present there is not so much difference." He says, furthermore, that he has "formerly analysed the water from some of the old city pumps, and found it to contain pretty uniformly, chlorides of calcium, magnesium and sodium, sulphates and carbonates of lime and magnesia, with iron and organic matter. The total residuum from the evaporation of a quart was in some 80 grains, others 44 and 32, and in one 20 grains.

Specific gravities of these waters. A series of experiments was performed in order to compare the density of the several specimens with distilled water. The weighings were made in a glass bottle with a perforated stopper, and holding a known quantity of pure water of 60° Fahr. Every care was used to have the weighings exact, and a correction for temperature was applied and the results were repeated. Still three of the waters presented the singular anomaly of being lighter than pure water. The presence of a large quantity of gaseous matter might account for this. The results are given below.*

Number of Water	1	2	3	4	5
Specific gravity,	1.000541	1.000060	1.0000894	1.000016	1.000118
Number of Water	6	7	8	9	10
Specific gravity,	0.999842	1.000062	0.999924	1.000090	0.999967

Action of the waters on lead. It now only remains for us to consider the result of the experiments conducted with a view to ascertain the action of these waters on metallic lead. Soon after they were received I set on foot this inquiry, in order to have as much time as possible to give the results maturity. To imitate as closely as we were able the condition of a leaden pipe full of water, a series of well stopped bottles, holding about a pint each, was prepared and numbered, and filled quite full of the several waters. A slip of lead, recently passed through the rolling mill and quite bright and clean was prepared, about half an inch wide and ten inches in length, and was placed in each bottle. The

* Besides carbonic acid, other gases, particularly nitrogen and oxygen, (not in the same proportion as in common air) are always present in waters and may account for the lightness of some of the waters in the table.

weight of each slip of lead was noticed carefully before the experiment, and all the bottles (each containing its slip of bright lead) were tightly stopped and placed in a dark closet. The only condition of lead in water pipes running full bore which was not met by this arrangement was in the fact that, as leaden pipes are soldered together and to the pumps or brass cocks, and as the solder and brass fixtures are more highly electro-negative than lead—chemical action is more likely to take place on it than if not thus situated. It would therefore have been well had there been an independent series of comparative experiments instituted to determine this point (by imitating the exact electrical condition of the lead) but the time allotted to the research was too limited to allow of a repetition for this purpose.

A bottle of pure distilled water was at the same time placed aside with lead, under the same conditions, for the sake of comparison. After about five weeks the bottles were opened and examined. The most visible and apparently the greatest action had taken place in No 1 ; the slip of lead in this water was tarnished and its spots much corroded, particularly where it had touched the bottle, and the water was milky from the suspension of minute crystalline flakes. The lead sparkled from the adhesion of small white crystals, and its edges had a cauliflower or fungus growth of yellowish semi-tranparent matter. This action had increased steadily from the first day and was quite evident within 24 hours from the commencement of the experiment.

No. 2.   The lead in this water looks as bright and fresh as the day it went in, and the water itself is not in the least turbid.

No. 3.   The lead discolored in streaks, having a few puce colored spots of a fungous growth, like organic matter ; some of this brownish matter, loosened from the lead, floated about like filaments of fibre.

No. 4.   Quite bright and not much acted on.

No. 5.   Much as No. 3, with like brownish spots. Water clear and no action apparently since the first few days.

No. 6.   Very slightly acted on—much like Nos. 3 and 5.

No. 7.   Slight, like Nos. 5 and 6—some brown matter floating.

No. 8.   A considerable number of light yellowish white cauliflower concretions, on the edges of the lead, spongy and light—while numerous particles of like appearance were floating in the liquid.

No. 9.   The lead not much acted on ; the edges covered with brown spots of fungus growth—but the matter which

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renders this water turbid in its natural state, was all precipitated—leaving it quite clear.

No. 10.   The lead apparently unattacked and bright, but the brown color of the water had entirely disappeared and a precipitate like hydrous peroxide of iron occupied the bottom of the bottle, as it would seem, owing to a combination of the organic matter of the water with the lead.

In the following table are given the weights of lead before the experiment and after, and the loss as well as the quantities of water in each experiment.

Number of water.	1	2	3	4	5	6
Weight before trial.	200.664	185.328	198.625	206.193	198.486	216.521
Weight after trial.	200.077	185.328	198.533	205.691	198.533	215.475
Diff + or —	—0.587	000.000	—.093	—.502	+.046	—.046
*Quantity of water.	.215	.211	.212	.200	.211	.229

Number of water.	7	8	9	10	Pure Water.
Weight before trial.	202.502	203.675	126.587	194.286	149.39
Weight after trial.	202.440	203.626	196.479	194.069	143.923
Diff + or —	—.062	—.049	—.108	—.216	—5.467
*Quantity of water.	.219	.214	.225	.209	.233

* The quantity of water was determined in a French half *litre* of glass, carefully graduated into 250 equal parts, of which the above are parts.   The *litre* is a little more than one quart.

After removing the solid matters from Nos. 1, 9 and 10 by filtration, hydro-sulphuret of ammonia was added to each bottle which was attended with an immediate discoloration in all. In No. 2 it was very slight indeed. Nos. 1, 10 and 9 were also but little discolored, proving that the lead in these waters had formed insoluble compounds and that the water was in reality, but little contaminated after removing the solid matter by filtration. Nos. 3, 5, 6, 7 and 8 were each more intense in color under the action of the susphurated hydrogen in the order of the numbers—No. 8 was quite black.

The pure water had acted on the lead more than any other. This is in accordance with a fact well known to chemists, that pure water is a much more powerful solvent of lead than water containing saline matters. We see also that the water which contains the most carbonic acid (No. 2) and the most but one of solid matter, had no effect whatever on the lead.

These facts certainly appear anomalous, and lead to the conclusion that we are yet without the means of establishing any general rule by which we may judge whether any given water will act on lead; and that actual experiment in every case is required before the question can be decided. The crystalline compound of lead seen in No. 1, was mainly carbonate of lead. This is one of the worst froms in which this metal can enter the human system, for although insoluble in water and tasteless, as soon as it enters the stomach the free acids, always there present, dissolve it and enable it to exert its deleterious influence.

It has been asserted on high authority (from experiments performed on some of the lower animals) that the carbonate and acetate of lead (i. e. *white lead* and *sugar of lead*) are the only salts of lead which are capable of producing any deleterious influence on life; while by the same authority we are informed that the chloride and nitrate of lead are nearly or quite inert as regards any poisonous influence.

It is quite interesting to observe that in Nos. 9 and 10, the organic matter had formed almost insoluble compounds with the lead—these waters presenting very little evidence, on addition of the sulphureted hydrogen, of the presence of that metal.

Practical inference from the foregoing results. Considering the deadly nature of lead poison, and the fact that so many natural waters dissolve this metal, it is certainly the course of safety to avoid, as far as possible, the use of lead pipes for conveying water which is to be used for drinking. The best substitute is found in a pipe well coated with *pure*

tin on the interior—such pipes being quite safe and in every way to be preferred.*

APPENDIX TO THE FOREGOING REPORT.

[Water No. 11.   From a well on the premises of James K. Mills, Esq., No. 20 Beacon street, Boston; taken Oct. 13.]

After nearly all the foregoing results were obtained, I received from you an additional water for examination, marked " *Aqua* 11." There was less than one standard gallon—a quantity too small to enable me to present the most satisfactory results ; but the character of this water was so decided, and the quantity of foreign matter which it contained so considerable, that very little difficulty was experienced in determining its leading constituents.

It was colorless in the quantity observed, had some light brownish sediment floating about on agitating the bottle, was free from smell, and had a well marked saline taste which was a little nauseous, on holding a quantity for some time in the mouth—reminding me of the old pump water of New York before the days of the Croton.

Chemical reaction.   Decidedly *acid* reddening litmus powerfully ; nitrate of silver produced a copious precipitate of chlorides, blackening quickly on exposure to light from the presence of organic matters.   The unconcentrated water gave a decided precipitate of sulphate of baryta on adding the nitrate of baryta—showing the presence of a notable quantity of sulphuric acid.

On boiling, carbonic acid gas was liberated and a granular white precipitate of carbonates was deposited.   Nitric acid was detected by the usual method.   Bromine and iodine were searched for in the precipitate by chloride of silver but were not found.   Phosphoric acid was largely present in combination with alumina, as shown by the method already described in the first part of this report.   Silicic acid was also present and crenic acid in notable quantity.   Lime, alumina, a trace of iron, and magnesia, were all detected by their appropriate tests.

This water has a specific gravity of 1.001126—which will be seen to be much higher than any of the others, indicating of course a larger proportion of solid matter.

The quantity of carbonic acid was determined by a different process† from the foregoing, which proved it to contain 35.04 cubic inches to the gallon.

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* My particular acknowledgments are due to my friend and pupil, Mr. THOMAS S. HUNT, for his efficient assistance throughout these investigations.

† The process alluded to consisted in adding to a known quantity of the water, caustic ammonia and chloride of barium—and air being carefully excluded the mixture was boiled ; the precipitate which fell (consisting of all the sul-

The total amount of solid matter was determined by the very slow evaporation of one fourth of a gallon, standard measure, in glass; when reduced to about two ounces it was transferred to a platinum vessel and carried to dryness over a steam bath. An abundant white granular powder adhering to the vessel fell during evaporation. The total amount of solid matter, as determined by this method, when dried carefully at a moderate heat and cooled over sulphuric acid in a vacuum, gave for the United States standard gallon—51.27408 grains.

This solid residue had a white rather grayish appearance, with but little crystalline matter. It was gently ignited in the same platinum vessel in which the evaporation had been completed and this operation was repeated until after cooling over sulphuric acid, a constant weight was obtained. The loss of organic and other volatile matter by this process was 1.2189 grains, which deducted from the total above, leaves us of anhydrous solid matter 50.05509 grains.

A different method was employed in the analysis of this water from that described in the former part of this report.

One standard quarter gallon of the water was boiled with the previous addition of a certain quantity of pure anhydrous carbonate of soda which threw down, during the progress of the ebullition, all the earths and other bases present except the soda, converting them of course into carbonates. Then, by the well known methods of analysis, the various ingredients were separately determined. I give subjoined the *actual* quantities obtained for one gallon of the water, without attempting to reconstruct the order of arrangement which we may suppose they had in nature. We have

Chlorine,	11.8084
Sulphuric acid,	4.9683
Lime,	10.5853
Magnesia,	4.3922
Alumina and oxide of iron,	.9884
Phosphate of alumina,	3.8857
Silica,	6.1158
Carbonate of soda, equivalent of Nitric and crenic acids and loss,	7.3209
	50,0550

Volume of carbonic acid in one gallon, 35.04 cubic inches.

phuric acid of the water united to barium and also all the carbonic acid as carbonate of baryta) after being well washed on a prepared filtre, was treated with hydrochloric acid. This dissolved and carried through all the carbonate of baryta as chloride of barium, leaving on the filtre the sulphate of baryta equivalent to the sulphuric acid of the water; from the filtrate the baryta equivalent to carbonic acid, is thrown down as sulphate and weighed, and from its weight the quantity of equivalent carbonic acid is calculated. This method is capable of great accuracy, and possesses the advantage of determining both sulphuric and carbonic acids at one operation.

No potash is associated with the soda in this water. The quantity at my disposal was insufficient for a more thorough analysis, but it is believed that the above results are very close to the truth. If more of the water had been at my command, I would have determined the organic matter quantitatively and have made an examination of its action on lead, which I am persuaded would be very marked. Some chemists have confidently affirmed that the presence of salts of sulphuric acid in a water will effectually prevent its action on lead. This cannot be considered true in an unrestricted sense, as is shown by the results given in this report.

Both the silica and phosphate of alumina in the analysis of No. 11 were separately analyzed after their weight was recorded, to ascertain their entire purity and freedom from other substances. On comparing the analysis of this water with those before recorded in this report, we notice several points of difference. No. 1 is the only water which approaches it in quantity of matter, but nearly two thirds of the impurities in that water are common salt, while the leading ingredients of this water (No. 11) are chlorides of lime and magnesium—rendering it a *very hard* water, totally unfit for the purposes of common life. The proportion of silica is also uncommonly large, as well as of sulphate of lime, both which would form, on evaporation, insoluble crusts on the flues of steam boilers and locomotives, should manufacturers and railroad companies be driven to the necessity of employing so bad a water for generating steam.

It cannot be doubted that the waters examined during this research—all of which it is presumed are the product of a granitic region—are materially different from those of a different geological formation, such, for instance, as those of a limestone country—or from an alluvial plain. All natural waters may in a certain sense be properly called *mineral waters*, as they must each possess a specific and peculiar character dependent on the nature and amount of solid matters which they contain, which ultimately must depend on the geological structure of the country where they are found. It is curious and instructive to see that even those waters which we consider the purest, all contain, in a notable quantity, matters which are essentially indispensable to satisfy the demands of the vegetable world (and ultimately the animal also); and when we remember the vast amount of evaporation from the expanded leaves of a full grown forest tree during a single summer day—can we any longer be at fault for a cause sufficient to account in the most satisfactory manner, for the various inorganic constituents of plants? But

such reflections belong better to some other occasion than the present report—and I must beg leave, dear sir, to submit the foregoing for your consideration, while I remain

<div style="text-align:center">With great respect,</div>

<div style="text-align:center">Your obedient servant,</div>

<div style="text-align:right">B. SILLIMAN, JR.</div>

New Haven, Ct.,
Yale College Laboratory, Oct. 29, 1845.